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Review

Development and restructuring of Turkey's electricity sector: a review

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Abstract

With a young and growing population, low per capita electricity consumption and rapid urbanization, Turkey for nearly two decades has been one of the fastest growing power markets in the world. The main objective of the present study is to review many aspects of the Turkish electricity sector, including its historical development, energy related emissions, and energy and exergy utilization efficiencies.

With the foundation of the Republic in 1923, Turkey's electricity sector has grown rapidly from 32.8 MW to 26.1 GW at the beginning of 2000. During this period, different governments implemented various strategies and policies for the Turkish electricity industry. In the 1980s, a new era for the industry and regulations started, allowing the installation of electricity power plants. Regulations allowed different investment models and the decision was taken highly to attract foreign investors.

Restructuring of the electricity sector in Turkey has started with the establishment of the Energy Market Regulatory Authority (EMRA) upon law No. 4628 which came into force on 3 March 2001. The Energy Market Regulatory Board, which runs the EMRA, was commissioned on November 19, 2001. In May 2002, the EMRA issued drafts of the Energy Market Licensing Regulation and the Electricity Market Tariffs Regulation, and these regulations went into effect in August 2002. The Electricity Market Implementation Manual was issued by the EMRA in April 2003. At present, not only the electricity sector, but also the whole Turkish energy sector is in a dynamic change.

Keywords: Electricity market; Power sector; Restructuring of electricity sector; Turkey

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Nomenclature

ε_1	energy (first law) efficiency (%)
ε_2	exergy (second law) efficiency (%)
$\varepsilon_{1,o}$	overall energy (first law) efficiency (%)
$\varepsilon_{2,o}$	overall exergy (second law) efficiency (%)

Abbreviations

AQPR	air quality protection regulation
Bcm	billion cubic meters
BOO (or BO)	build own operate
BOT	build operate and transfer
DSI	state hydraulic works
EIE	general directorate of electrical power resources survey administration
EMIM	electricity market implementation manual
EML	electricity market law
EMRA	energy market regulatory authority
EU	European union
FGD	flue gas desulfurization
GDP	gross domestic product
IEA	International energy agency
ktoe	kilo tons of oil equivalent
LPG	liquefied petroleum gas
Mcm	million cubic meters
MENR	ministry of energy and natural resources of Turkey
Mt	million tons
MTA	general directorate of mineral research and exploration institution
Mtoe	million tons of oil equivalent
NCCG	national climate coordination group
NECC	national energy conservation center
OECD	organization for economic cooperation and development
TEAS	Turkish electricity generation transmission co.
TEDAS	Turkish electricity distribution co.
TEIAS	Turkish electricity transmission co.
TEK	Turkish electricity administration commission, Turkish electricity authority
TETTAS	Turkish electricity trading and contracting co.
TEUAS	Turkish electricity generation co.
toe	tons of oil equivalent
TOR (or TOOR)	transfer of operating rights
TPP	thermal power plant
UNFCCC	united nations framework convection on climate change
WEC-TNC	world energy council-Turkish national committee

1. Introduction

Energy is essential for economic and social development and improved quality of life in Turkey, as in other countries. Much of the world's energy, however, is currently produced and consumed in ways that cannot be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be focused on efficiency in energy production, transmission, distribution and consumption in the country. On the other hand, electricity supply infrastructure in Turkey, as in many developing countries, is being rapidly expanded, as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth. On the contrary, in the coming decades, global environmental issues could significantly affect patterns of energy use around the world, as in Turkey. Any future efforts to limit carbon emissions are likely to alter the composition of the total energy related carbon emissions by energy source in the country [1].

Turkey, with a population of about 67,803,927 in 2000, is located between 35°50′ and 42°06′ north latitudes and 25°40′ and 44°48′ east longitudes. Most of Turkey is in Asia. The far northwestern part of the country is in Europe and is separated from the rest of the country by the Dardanelles and Bospherous Straits and the Sea of Marmara. Some basic socioeconomic data for the country are shown in Table 1 [2–5]. Urban population as a percentage of the total population has sharply increased from 34% in 1965 to 65.03% in 1997, representing an average urbanization growth of about 2% annually. Turkey also has the highest population growth rate of all International Energy Agency (IEA) countries. The total population is expected to exceed 83 million by 2002 [4,5]. Besides the other social factors, in this rapid growth in population, Turkey is experiencing high domestic migration rates toward urban areas and in particular, toward the western portion of the country [4].

Economic growth in recent years has been associated with the privatization of public enterprises. The macroeconomic performance was boosted by growth in the energy sector. The industry and services sectors are predominant. From 1984 to 1994, the share of

Table 1
Some basic socioeconomic data of Turkey [2–5]

Description	Value
Population (in 2000)	67,803,927
Annual population increase rate (%)	1.44
Urbanization ratio (% in 2000)	59.25
Urban population growth rate (% for the period of 1985–1990 and 1990–2000)	43.9 and 32.6
Geographical area (km^2)	780,576
Gross national product (GNP) per capita (US$ in 2000, 2001 and 2002)	2965, 2123 and 2584
Energy intensity: energy use per unit of GDP (keo/US$ in 2000 and 2001)	8.15 and 9.01
Energy consumption per capita (koe[a] in 2000 and 2001)	1219 and 1138
Net electricity consumption per capita (kW h in 2000 and 2001)	1458 and 1416
Carbon dioxide emissions per capita (metric tons in 2000 and 2001)	3.37 and 3.14

[a] Kilogram of oil equivalent.

the agricultural sector dropped from 19.6 to 16.2%, while those of industry and services rose from 28.6 to 30.2% and from 51.8 to 53.5%, respectively. In Turkey, electricity is produced by thermal power plants, by consuming coal, lignite, natural gas, fuel-oil and geothermal energy, wind energy (recently) and hydropower plants. There is no nuclear power plant in Turkey as yet. However, according to the long-term energy plan, the first nuclear power plant with a capacity of 1000 MW will be in operation in 2005 [6].

2. Turkey's total input configuration

Turkish energy consumption has risen dramatically over the past 20 years due to the combined demands of industrialization and urbanization. Table 2 shows the structure of total energy production in Turkey in the years of 1990, 1995 and 2000, while total energy (consumption) input during the same period is given in Table 3. The differences between the values given in Tables 2 and 3 indicate import energy. The basic energy values here are based on the data provided by the World Energy Council-Turkish National Committee (WEC-TNC) [5,7–9]. As can be seen in Table 3, total energy inputs to the Turkish sector were 2236.32 PJ in 1990, and 3527.33 in 2000 with an average increasing rate of 4.23% annually. Of the total energy input, 48.38% was produced in 1990, while this value was 34.59% in 2000. The total share of energy imported continued to increase between the years considered. In 2000, of 10 energy sources, petroleum had the biggest share with 41.89%, followed by lignite with 15.15%, natural gas with 16.20%, and hard coal with 11.02%. In the last three years, renewable energy source production was the second biggest production source after total coal production, while renewable sources provided about 16% of the input [10].

According to planning studies, Turkey's final consumption of primary energy is estimated at 130 million tons of oil equivalent (Mtoe) in 2005, 171 Mtoe in 2010, and 298 Mtoe in 2020. In other words, in 1999, the domestic energy production met 36% of

Table 2
Turkey's energy production values in the years 1990, 1995 and 2000 [5,7,9]

Energy carrier	toe[a]	1990		1995		2000	
		PJ	%	PJ	%	PJ	%
Hard coal	0.61	69.99	6.47	57.32	4.81	57.60	4.84
Lignite	0.21	389.80	36.03	463.11	38.89	534.18	44.89
Asphaltite	0.43	4.96	0.46	1.20	0.10	0.40	0.03
Petroleum	1.05	163.14	15.08	154.32	12.96	120.65	10.14
Natural gas	0.91	8.06	0.75	6.92	0.58	24.31	2.04
Wood	0.30	224.09	20.71	230.41	19.35	212.40	17.85
Biomass	0.23	77.20	7.13	65.04	5.46	57.50	4.83
Hydropower	0.086	104.16	9.63	159.88	13.43	138.76	9.33
Geothermal	0.86	39.29	3.63	47.09	3.95	64.81	5.22
Solar	0.86	1.01	0.09	5.14	0.43	9.42	0.79
Wind	0.086	0.29	0.03	0.31	0.03	0.39	0.03
Total		1082.00	100.00	1190.74	100.00	1220.42	100.00

[a] Tons of oil equivalent.

Table 3
Turkey's total energy consumption in the years 1990, 1995 and 2000 [5,7,9]

Energy carrier	toe[a]	1990		1995		2000	
		PJ	%	PJ	%	PJ	%
Hard coal	0.61	208.85	9.34	217.96	8.05	388.82	11.02
Lignite	0.21	428.81	19.17	460.01	16.99	534.19	15.14
Asphaltite	0.43	2.50	0.11	1.19	0.04	0.40	0.01
Petroleum	1.05	996.30	44.55	1225.32	45.25	1477.60	41.89
Natural gas	0.91	130.01	5.81	263.87	9.74	571.30	16.20
Wood	0.30	224.09	10.02	229.13	8.46	212.40	6.02
Biomass	0.23	77.20	3.45	68.01	2.51	57.50	1.63
Hydropower	0.086	104.16	4.66	159.88	5.90	138.76	3.93
Geothermal	0.86	39.29	1.76	44.76	1.65	64.81	1.84
Solar	0.86	1.01	0.05	4.64	0.17	9.42	0.27
Wind	0.086	0.29	0.01	0.28	0.01	0.39	0.01
Coke	0.70	1.20	0.05	2.10	0.08	21.13	0.60
Petrocoke	0.77	22.60	1.01	30.80	1.14	50.85	1.44
Total		2236.32	100.00	2707.94	100.00	3527.33	100.00

[a] Tons of oil equivalent.

the total primary energy demand and will probably meet, with a decreasing rate, 28% in 2010 and 24% in 2020 [2,5,11]. In 1990 and 2000, of Turkey's total end use energy, 35.6% and 40.57% were used by the industrial sector, followed by the residential–commercial sector at 39.45 and 34.10%, the transportation sector at 21.45 and 21.02%, the agricultural sector and the nonenergy (out of energy) use at 3.41 and 4.30%. These figures clearly indicate that the total share of the industrial sector increased, while that of the residential–commercial decreased. The share of the industrial sector in this breakdown is expected to continue to grow at approximately 9% per year and reach 49 and 59% in 2010 and 2020, respectively. As Turkey's economy has expanded in recent years, the consumption of oil has increased. This growth in consumption is expected to continue up to the year 2020 at a rate of about 4.5% per year. The proportion of oil estimated to decrease somewhat as natural gas usage increases. It is projected that these figures will be 29% for oil, 35% for coal, and 11% for natural gas by 2020 [10,12].

3. A historical development of the Turkish electricity market

Electricity, distributed to every stationary requirement for light and power, is the defining innovation of human history, replacing muscle power and candles with on-demand power. In the first 100 years post-commercialization in 1880, optimal generation technologies were inherently remote, or central [13]. In 1879, the first commercial power station was opened in San Francisco, USA, which used Brush generator and arc lights [14].

In 1832, Michael Faraday (England) announced that he had converted magnetism into electricity. He had sent a current through a coil of wires, creating a magnetic field which induced a momentary current in a second coil. In America, Joseph Henry affirmed that he

had done much the same thing at about one year earlier. The discovery of electromagnetic induction led to the development of electric motors, generators and dynamos [15].

Coming to Turkey, the first electric generator was a 2 kW dynamo connected to the water mill installed in Tarsus, Turkey, in 1902. The first bigger power plant was installed in Silahtaraga, Istanbul, in 1913. Since then, the following evolution in time of the Turkish electricity market has occurred [16].

3.1. Foreign investment period (1923–1930)

During this period, the electricity industry was heavily dependent on foreign investment and this was a harmonious choice for the government as the country was trying a liberal economy. Mostly, German, Belgium, Italian and Hungarian companies joined in providing electricity. A good example is the joint venture between the German company MAN and AEG that built a diesel generator in 1925 in Ankara. The first Turkish electricity company, Kayseri ve Civari Elektrik Turk Elektrik, Inc., was established in 1926. At the end of this era, there were 48 power plants (74.8 MW) producing 106.3 GW h electricity and per capita electrical consumption was 6.2 kW h [17].

3.2. Nationalization (1930–1950)

The 1930s had demonstrated the beneficial effects of public ownership on restructuring the electricity industry all over the world. As for Turkey, the government implemented a 5- year industrial plan in 1933 which suggested the government play an active role in the electricity industry by searching for hydro and thermal sources for power generation. This was followed by a legislation that allowed the municipals to build and operate power plants. In 1935, Etibank, Mineral Research and Exploration Institution (MTA) and Electrical Power Resources Survey Administration (EIE) were been founded; later the Bank of Provinces and State Hydraulic Works (DSI) were established. So, the installed capacity had been 126.2 MW at that time, while the generation was 213 million kW h and the number of the electrified provinces was 43. In 1941, the installation of Zonguldak-Catalagazi Electricity Power Plant was started by Etibank which was a coal based power plant. Nationalization of the electricity industry had started in 1938 and finished in 1944. The only company that was not nationalized was Kayseri ve Civari Elektrik Turk Elektrik, Inc., which was a 100% private Turkish company. In 1948, Catalagazi Thermal Power Plant was put into service and the network of Istanbul was reinforced by a 154 kV transmission line erected in 1952. The construction and operation of the power plants by state utilities and private sector entities were started in the 1950s. At the end of 1950, Turkey's electrical capacity was 407.8 MW generating 789.5 GW h electricity, 23% of the population used electricity, while per capita consumption increased to 32 kW h [16–19].

3.3. Development plans and back to the mother (1960–1980)

The government started the development plans era which was more of a national policy than a global one. The Ministry of Energy and Natural Resources of Turkey (MENR) was established in December 1963, and was responsible for Turkey's energy policy. This was

followed by passing the law creating the Turkish Electricity Administration Commission (TEK) which would create a monopoly in the Turkish electricity sector at all stages. All generation assets were passed to TEK except the ones that belong to Cukurova Elektrik T.A.S. and Kepez ve Antalya Havalisi Elektrik Santralleri T.A.S. The transmission and distribution business, which was managed by the municipals, were left to the local governments. From 1970 to 1980, hydroelectricity capacity increased from 725 to 2131 MW, while the thermal capacity increased from 1510 to 2988 MW. In total, the Turkey's electrical capacity increased. It more than doubled, from 2235 to 5199 MW. At the end of 1980, electricity generation was 23,275 GW h and nearly 80% of the population was electrified. In 1970, growing generation, distribution and consumption of electricity as well as the necessity of expanding the respective services made it essential the forming of an institutional structure and thus the Turkish Electricity Authority (TEK) was established. So, the integrity in the power sector was ensured, with the exception of municipalities and the Bank of Provinces. At that time, the installed capacity reached 2234.9 MW, while generation reached 8.6 billion kW h levels [16–19]. Turkey was impacted too by the worldwide energy crisis in the years between 1970 and 1980, and the supply–demand balance was spoiled due to largely outer-dependence on the fuel of thermal power plants so, compulsory electricity disruptions were applied. Despite to the above mentioned inconveniences, Turkey's installed capacity reached 5118.7 MW in 1980, while power generation amounted to 23.3 billion kW h [16–19].

3.4. Investment models (1980–2000)

During 1980s, once again liberalization in economy dominated the country and incentives were given to the private sector to invest. First, the government enacted the 2705th law in 1982 that passed all the assets to TEK form municipals. By doing this, the first aim was to centralize the industry to facilitate the infrastructure for private companies. Secondly, the law took over TEK and DSI's oligopoly on building power plants and allowed the private sector to build power plant and sell their electricity to TEK. In 1982, all the electrical installations and networks belonging to municipalities and unions were transferred to TEK. Since then, all energy sales including to villages have been conducted by TEK. In this year, installed capacity and energy generation reached 6638.6 MW and 26.6 billion kW h, respectively. In 1984, the monopoly of TEK was lifted and the private entities formed against permissions were also given the opportunity to intervene generation, transmission and distribution of electricity. In the same year, by re-organizing its legal status, bodies and structure, TEK had gained the identity of state-owned enterprise. About 10 private entities were entitled to do the generation, transmission, distribution and trade of electricity within their legal district boundaries between 1988 and 1992. TEK had been incorporated in the scope of the privatization by the decree of Law No. 513 and dated August 13, 1993, which was issued 23 years after its founding whose relations with the MENR would be on going. As a continuation of this arrangement, it was split into two separate state-owned enterprises, namely 'Turkish Electricity Generation Transmission Co. (TEAS)' and 'Turkish Electricity Distribution Co. (TEDAS)', by the Act of the Council of Ministers.

3.5. Restructuring the electricity market (2000–present)

By Electricity Market Law No. 4628, issued in the Official Gazette dated 3rd March, 2001, concerning the restructuring of the energy sector, the establishment of financially strong, stable and transparent electricity market under competitive and special law provisions has been targeted for a sufficient, high-quality, continuous, low-cost and environment friendly supply of electricity to the disposal of consumers as well as the maintaining of an independent regulatory and supervisory framework. This law covers the generation, transmission, distribution, wholesale, retail and respective services of electricity including its import-export and also the rights and responsibilities of all real and legal persons connected with those services and establishment of a Regulatory Body of Electricity Market and its running procedures and principals as well as the procedures to be followed for the privatization of the electricity generation and distribution assets. By the Decree of Council of Ministers No. 2001/2026 and dated February 5, 2001, which was issued in the Official Gazette dated 2nd March, 2001, TEAS was decided to be restructured to form three state-owned public enterprise, namely Turkish Electricity Transmission Co. (TEIAS), Turkish Electricity Generation Co. (TEUAS) and Turkish Electricity Trading and Contracting Co. (TETTAS) [16].

The MENR has planned for a very large increase in electric generating capacity over the next 20 years. According to forecasts prepared by the MENR, the country will need about an electric power capacity of 65 GW by 2010, and about 105 GW by 2020. Electric energy generation capacity is expected to have to rise from about 117 TW h in 2001 to more than 347 and 624 TW h in 2010 and 2020, respectively. This implies power demand growth rates of at least 8% per annum for the coming decade and at least 6% per annum for the following decade [20,21]. At present, not only the electricity sector, but also the whole energy sector in Turkey is in a dynamic change.

4. A brief outlook on the Turkish electricity market law and regulations

4.1. Electricity market law

In the beginning of the year 1993, the National Energy Conservation Center (NECC) of Turkey was established within the body of the EIE. Although the EIE has been conducting energy conservation studies throughout the country since 1981, to date no Energy Efficiency Law in Turkey could be enacted. There are, however, some studies conducted by the MENR. In these studies, with the leading factor of the NECC, a committee formed by representatives of several public and private sectors and universities, prepared the Energy Efficiency Law Sketch. If this law becomes effective, all the people and establishments in the industry, building and transportation sectors will need to address the energy efficiency subject at the same level as in developed countries. Furthermore, energy consumption and energy efficiency studies of commercial and industrial establishments will be controlled, so that efficiency will be increased [19].

As for Electricity Market Law (shortly EML), it was enacted under Law No. 4628 on 3 March 2001 to unbundle electricity market activities, enable progress into a liberalized

electricity market and provide fair and transparent market regulation. The Electricity Market Regulatory Authority was established as per EML and was later renamed as Energy Market Regulatory Authority (EMRA) as per the provisions of Natural Gas Market Law No. 4646. Members of the Energy Market Regulatory Board assumed duty on November 19, 2001 [22].

The EML consists of two parts, namely (i) general provisions, and (ii) the electrical markets regulatory council and various provisions. The first part includes two sections: (i) purpose, scope and definitions, and (ii) electricity market activities and license, while the second part covers four sections: (i) the responsibilities and authorities of electrical markets regulatory authority and electrical markets regulatory council, (ii) sanctions and the right to sue, (iii) tariffs, supporting consumers, privatization and other provisions, and (iv) provisional clauses.

The purpose of the EML is to ensure the formation of a financially strong, stable and transparent electrical energy market and an independent regulation and supervision of this market which can operate according to private law provisions in a competitive environment so that electricity can be supplied to consumers in a manner which is sufficient, quality, regular, low-cost and environment friendly. This law covers production, transmission, wholesale, retailing and retailing services and import and export of electricity and the rights and obligations of all the real and juristic persons related to these activities, working procedures and principles regarding the establishment of the EMRA and the procedure applicable to privatization of electricity production and distribution assets [23].

4.2. Electricity market implementation manual and regulations

In May 2002, the EMRA issued drafts of the Energy Market Licensing Regulation and the Electricity Market Tariffs Regulation, and these regulations went into effect in August 2002. The EMRA has announced a four-stage approach to a competitive electricity market. The first stage grants licenses to firms in the electricity and natural gas markets, while the second stage will give large industrial users the right to choose their electricity provider. The third stage will start to set up the Market Financial Reconciliation Center for balancing and settlements, and the fourth stage will make this center fully operational. Legislation has been proposed in the Turkish Parliament that would expand the scope of the EMRA to include the upstream activities in the petroleum market. This Petroleum Market Bill is expected to be considered by the parliament in the near term [21].

Within the scope of the studies conducted by the EMRA, the following regulations have also been issued [22]:

- Electricity Market Licensing Regulation (August 2002)
- Electricity Market Tariffs Regulation (August 2002)
- Electricity Market License Fees (August 2002)
- Eligible Consumer Regulation (September 2002)
- Import and Export Regulation (September 2002)
- Customer Service Regulation (September 2002)

- Communiqué Regarding Wind and Solar Measurements (October 2002)
- Communiqué Regarding Meters (December 2002)
- Grid Code (January 2003)
- Distribution Code (February 2003)
- Communiqué Regarding Regulatory Accounting Guidelines (January 2003)
- Communiqué Regarding Settlement (March 2003)
- Communiqué Regarding Connection and Use of System (March 2003)
- Electricity Market Import and Export Regulation (April 2003).

In April 2003, the Electricity Market Implementation Manual (EMIM) was issued by the EMRA. The EML also foresees the establishment of a market model based on bilateral contracts between market participants and a balancing and settlement mechanism. The realization of the market model envisaged in the EML necessitates a privatization process in line with the market objectives and the formation of a freely negotiable supply margin. Within this context, the establishment of a non-discriminatory, competitive and transparent market structure is of central importance. As market risks are minimized through regulations, confidence is established and the market is gradually liberalized based on a schedule, it will become more appealing for foreign and domestic private investors.

The achievement of the objectives of this reform process requires the acceptance of the reform by all market participants and cooperation toward a common objective. The sustainability of a structure with such a wide scope ranging from generation to consumption and involving interwoven processes such as regulation and implementation in closely related to the development regulations with clear and transparent provisions and to the establishment and realization of a participatory mechanism for the formation, development and amendment of those regulations.

The purpose of the EMIM is to develop details of the issues that are crucial for the implementation process in order to ensure the realization of the following basic objectives foreseen in the law:

- Fostering competition in order to increase efficiency and decrease costs in the electricity sector;
- Establishing cost-reflective prices to ensure the financial viability of the sector;
- Facilitating private participation;
- Ensuring the stability of supply;
- Ensuring stability in wholesale prices until prices can completely be determined in a competitive environment (introduction of arrangements to prevent volatility and uncertainty of the price increases that will initially occur in order to cover costs);
- Allowing market participants adequate time to adapt to competitive conditions;
- Meeting stranded costs without the need for support form the state budget;
- With the market becoming more attractive for investors, the presence in the market of firms that are able to finance new generation capacity and are capable of meeting their financial obligations arising from energy sales and purchase contracts, and thereby ensuring the security of supply [22].

5. Assessment of the Turkish electricity market

The status of the Turkish electricity market in 2003, together with the projections of 2004, may be assessed as follows: the EMRA started grant license in 2003 for the first time. Investment license application by the private sector for electricity generation reached 8000 MW at the end of this year. The EMRA submitted approximately 3400 MW of these applications to examination and has granted license for an installed power of about 1000 MW, while it has taken a decision on the adoption of an installed power of 700 MW. The EMRA has carried out the tariff approval into effect for the first time on 21 March 2003. The tariff of TETTAS (the public wholesale corporation) which takes over the existing contracts, tariffs of transmission system and the tariffs of use of operating and transmission system, the distribution and retail sale tariffs of TEDAS and its subsidiaries have been approved. The EMRA attached importance to participation in tender in 2003 for the use of natural gas in cities. License tenders for natural gas distribution have been called for over 20 provinces. Problems regarding demand incorporation in the scope of free customer practices in electricity power, which began from 3 March 2003, are assessed and in this framework, it is suggested that the Electricity Market Free Consumer Regulations be amended in 2004. As required by law, the consumers whose annual electrical energy consumption exceeds 9 million kW h qualify as free consumer as from 3 March 2003. The rules to which TEIAS, distribution license owner body corporates and the transmission system users are obliged to conform in respect of the regulations, which will be published regarding the supply reliability and quality in electricity market, and providing the quality and sustainability of electric power, shall be determined. Thus, it shall be assured that the system works in a way that gives better quality and reliability [24].

The EMRA granted 161 licenses for electricity production, 132 for autoproducers, 59 for autoproducer groups and five wholesale licenses within 2003. Table 4 shows

Table 4
Distribution of licenses by fuel (energy) types as well as the breakdown of 132 autoproducers by sector [25]

Distribution of licenses by fuel (energy) types	
Type of fuel (energy)	Installed capacity (MW)
Natural gas	4505.38
Wind	281.21
Hydro	10,300.95
Coal	7825
Fuel oil/diesel oil	1607.16
Multi fuel	100.25
Geothermal	28.45
Biogas/cogeneration	1.39
Breakdown of 132 autoproducers by sector	
Name of sector (factory)	Quantity
Textile	34
Metallurgy/iron-steel factories	10
Food/sugar factories	35
Paper industry	13
Petroleum/chemical industry	15
Other sectors	25

the distribution of licenses by fuel types as well as the breakdown of 132 autoproducers by sectoral [25].

Of the 161 licenses, 36 belong to the private sector, while the rest relate to the plants in operation and under construction within the body of TEAS. The distribution of power plants installed by the private sector is as follows: six natural gas-fired plants, eight wind plants, 11 hydroelectric power plants and 11 fuel-oil, naphtha, biogas fired plants and geothermal power plants. Besides this, 91 hydroelectric power plants, 16 fuel-oil and diesel-fired plants, two geothermal power plants, 12 coal-fired plants and four natural gas-fired plants belong to TEAS.

The total installed capacity of 132 autoproducer licenses amounts to 2196.61 MW. The number of natural gas-fired power plants is 56, followed by fuel-oil-fired plants at 31, lignite/fuel-oil at 29, and other plants (using naphtha, LPG, biogas, waste gas, hydroelectric and wind energy) at 16.

The total installed capacity of 59 autoproducer group licenses is 2674.834 MW. The distribution of power plants according to fuel types is as follows: 39 natural gas-fired power plants, eight hydroelectric power plants and 13 naphtha-, LPG- and fuel-oil-fired power plants. As of end of November 2003, 18 companies made an application for receiving autoproducer license, representing a power capacity of 74.169 MW.

6. Private energy investment models

For restructuring the Turkish electricity sector, comprehensive and detailed studies to determine the basic parameters of the sector have been implemented by the MENR and the consultants. The main goal of these studies is to establish an institutional structure and the corresponding regulatory framework for the sector [26]. According to the MENR, besides the installed capacity up to 2020, major infrastructure projects would also require investments of US$ 4–4.5 billion per year in terms of transmission and distribution systems. Much of them would need to come from the private sector [27]. Thus, the MENR has conceived of some options for financing projects. In this regard, five types of investment models are in operation in Turkey: (a) build, operate and transfer (BOT), (b) build, own, operate (BO or BOO), (c) autoproduction, (d) transfer of operating rights (TOR or TOOR), and (e) conventional tendering system by TEAS [2,26,28,29].

The first three models are the most important for combined-heat power (CHP). Therefore, they are described in more detail in the following. Besides this, according to the Turkish Cogeneration Association (TCA), among these models, BO and autoproduction do not present problems [28].

6.1. BOT projects

Turkey was one of the first countries to conceive the BOT model as an alternative in implementing power projects to meet the growing need for public service investment [29]. The BOT model was first introduced in 1984. Under this model, private investors build and operate private sector generation facilities for several years, then, finally, transfer ownership (in this case) to the state. The electric power produced by these projects could

be sold to the national grid, the state-owned electricity authority, or even to a private end user. BOT projects have been plagued by legal problems, which have slowed their implementation.

6.2. BO (or BOO) projects

Law number 4283, issued in 1997, facilitated the BO model. Under BO, the developers retain ownership of the plant and can sell the electric power to an end user, the state-owned electric authority, or the national grid. The basic principle of the BO model is international competition with which the energy selling price (tariff) is fixed. Because of the legal obstacles faced by the BOT model under which investors have to transfer the facilities at the end of a certain period, priority has been given to BO models, which do not require the investor to hand back the investment [28,29].

6.3. Autoproduction

The production of electricity by industrial facilities for their own use in Turkey based on the Turkish Trade Law is called ‘autoproduction’. This option has minimal implementation problems. Decree number 85/9799, issued in 1985, is a legal document that gave the details of law number 3096 and put autoproduction into practice [26]. The decree of autoproduction has been revised several times to date in order to clear applications and extend the application area [29].

The BOO approach has been more favorably received by power developers, as this does not impose any time constraints on the project. As a result, the economics of power production is usually more favorable than that for the BOT approach, which results in a lower cost of power generation [23].

7. A brief overview of Turkey’s energy sources used for generating electric power

In Turkey, electricity is produced by thermal power plants (TPPs), geothermal energy, wind energy, and hydropower plants. Thermal resources meet approximately 60% of Turkey’s total installed capacity for electric power generation, while 75% of total electricity is generated from TPPs. Of the total thermal generation, natural gas accounts for 49.2%, followed by coal for 40.65, and 9.9% for liquid fuel [30]. When the fuels used in cogeneration plants are examined, it is seen that natural gas, liquefied petroleum gas (LPG), naphtha, diesel, coal and fuel oil are present [31]. Among fuel types used by autoproducers as of March 2000, natural gas accounted for about 64%, followed by fuel oil with 22% and the remainder with 14%. Natural gas is preferred as a fuel in regions where it is available because it is efficient, cheap, and clean [32,33]. In this regard, the following subsection will briefly review some of the above mentioned energy sources in terms of their potential and utilization.

7.1. Coal

Turkey accounts for almost 90% of the coal consumed in the Middle East. In 1999, Turkish coal consumption reached 84 Mt, most of it low calorific value, locally produced lignite [32]. As a result of the planning studies of the MENR, production and consumption of coal (both HC and LG) is expected to increase after 2002, primarily to fuel additional coal-fired generating capacity. Hard coal and lignite consumption is projected to increase by 139 Mt, from 8 and 46 Mt in 1990 to 147 and 185 Mt in 2020, respectively. Two projects currently in the construction phase include a 1210 MW hard coal-fired plant being built on the southern coast of Turkey near Iskenderun, to be fueled by imported coal, and a 1440 MW lignite-fired plant (Afsin-Elbistan B plant) being built in the Afsin-Elbistan region in southern Turkey. When completed between 2003 and 2005, the two plants could add more than 10 Mt to Turkey's annual coal consumption [34,35].

In 1999, Turkey's installed electricity capacity reached 26, 117 MW. Sixty percent of the total installed capacity was obtained from thermal resources, while the remainder came from hydro and geothermal resources. Until 1985, lignite-fired power plants were used, and had the largest share in the total thermal capacity. Since then, the share of lignite plants has gradually decreased. Recently, natural gas-fired generation has been gaining great importance. In 1999, the share of coal-fired plants in the total installed capacity was 26%, followed by natural gas at 24%, and oil at 6%. The coal share of energy consumed in Turkey for electricity generation is projected to be 30 and 27% in 2010 and 2020, respectively, with imported coal shares of 6 and 10% over the period, respectively [4,36].

7.2. Natural gas

Turkey is located at the strategic crossroad between the abundant oil and natural gas reserves of the Middle and Near East and primary consumers in Europe and America. Turkey consumes 30 Mt of crude annually, of which 24.6 Mt is imported. It is estimated that Turkey's total oil imports will reach approximately 42,000 ktoe by 2010 [37]. It was reported that natural gas import of Turkey reached 14,344 million cubic meters (Mcm) in 2000 [38].

Turkey's natural gas demand and supplies may be summarized as follows [39,40]:

(a) In Turkey, the first autoproducer natural gas-fired plant was installed in 1992. Following this application, many other cogeneration facilities using natural gas were established in the country. The use of natural gas in cogeneration plants has risen dramatically.
(b) Turkey continues to expand the use of natural gas. Currently, five municipalities, six industrial zones, 200 industrial plants, two fertilizer production facilities, and seven power plants utilize natural gas as an energy source.
(c) Current Turkish gas production of 0.85 billion cubic meters (Bcm) at 14 fields meets around 7% of domestic gas consumption requirements.
(d) In 2001, power generation had the biggest portion with 68.6%, followed by residential with 20.85%, industry with 9.80%, and fertilizer sectors with 0.75%.
(e) In Turkey, as in Europe and the United States, energy policies have had an important effect on the availability of natural gas and its development as a fuel for electricity

generation. In other words, the driving force behind the growth in Turkey is the increased consumption of natural gas for electric power generation.

(f) Turkish natural gas demand is projected to increase extremely rapidly in the coming years, with the prime consumers expected to be natural gas-fired electric power plants and industrial users.

7.3. LPG

LPG (or LP gas) stands for liquefied petroleum gas. Since the beginning of the 1960s, LPG has been used as an alternative to city gas and kerosene in Turkey, while the first LPG use in cogeneration plants was in 1996 in Denizli, Turkey. The consumption of petroleum products in 2000 was 34 Mt, of which about 13.2% was accounted for by LPG [41]. The share of oil in energy demand will drop from 52% in 1995 to about 36% in 2020, but it will remain the main energy source, while that of natural gas will jump from 11.3% in 1995 to 37% in 2010 [6].

Utilization of LPG as an energy sources in Turkey may be summarized below [41].

(a) Since the beginning of the 1960s, LPG has been used as an alternative to city gas and kerosene in Turkey. The recent expansion of the LPG industry in Turkey has demonstrated the long-term potential for the regional LPG markets.

(b) In 2000, the share of LPG and natural gas in the gas fuel market was 30 and 70%, respectively. It is also estimated that this ratio will change in favor of natural gas with the handling of new natural gas projects.

(c) In Turkey, the first LPG use in cogeneration was in 1996 in Denizli, Turkey. Following this application, many other cogeneration facilities using LPG were established in the country. The use of LPG in cogeneration plants is, however, under 1% today.

(d) In Turkey, LPG is marketed in three different segments, namely LPG cylinder, bulk storage (storage container), and autogas. Among these, autogas (or automotive LPG) is the branch that has grown the most of the three segments in recent years.

(e) In 2000, the consumption of petroleum products was 30 Mt, of which nearly 87% was accounted for by liquid fuel, while LPG constituted the rest.

7.4. Oil

The Turkish historian Evliya Celebi first mentioned the existence of oil in Turkey in the 18th century. Exploration began in the second half of the 19th century, when both domestic and foreign companies carried out exploration in Thrace. The first productive well, operated by the European Petroleum Company, was located in the Hora Deresi region (Thrace) [42,43].

According to the theoretical calculations, 954 Mt of oil reserves exist in Turkey's already known areas. Of this, 156 Mt is extractable oil. At the end of 2002, 117 Mt of oil was extracted and the remaining recoverable reserve amounts to 39 Mt. With the current production level and no additional reserve discovery, the production capacity will still be available for some 16 years [44].

In 2002, Turkey's crude oil production was 2.4 Mt, which corresponds to 8% of the total oil demand. Besides this, production has declined since the early 1990s. Oil is mainly produced in the southeast, with a small amount from the northwest of the country. In the coming years, oil production is also expected to decrease due to the natural depletion of the fields. During 2002, a total of nine companies, of which two and seven are domestic and foreign, have been in production activities as a single company or joint producing companies. Between 1990 and 2002, oil supply increased at an average growth rate of 2.2% annually. Oil consumption reached from 22.7 Mt in 1990 to 29.6 Mt in 2002. Final oil consumption of 24.2 Mt in 2002 corresponds to 42.7% of Turkey's total final energy consumption. In 2002, 8.3% of the total electrical energy generation came from oil-fired plants [44].

7.5. Hydro

The gross hydropotential, which is a function of topography and hydrogeology, is estimated to be 432,986 GW h annually for Turkey [36,45]. An evaluation of Turkey's hydropotential as of 2002 is illustrated in Table 5. The hydroelectric energy production of 23,148 GW h in 1990 reached 33,684 GW h in 2002 with an annual average growth rate of 3.2%. As of the end of 2002, Turkey's economically feasible hydropower potential amounts to about 126 billion kW h, of which 34% has been exploited. It is projected that the increase in the hydroproduction will continue in the coming years [44].

7.6. Geothermal

The estimated geothermal electrical power and direct use (heat) potentials are reported to be 4000–4500 MW_e and 31,500 MW_t, respectively. In addition, visible potential for electricity generation is 764.81 MW_e, while that for heat is 3173 MW_t according to the data given by the MTA [44,46,47]. The potential of geothermal development in Turkey is generally considered large in terms of moderate and low temperature resources (<150 °C). Therefore, the resources are mostly suitable for direct use applications [45]. The Denizli-Kizildere geothermal power plant, which is at present the only operating geothermal power plant in Turkey, produced an electrical energy of 105 GW h in 2002 [44].

7.7. Wind

Progress in wind energy technology in recent years has drawn private-sector attention to this energy resource. As a consequence, numerous companies have submitted their applications to the MENR for the construction of new wind power plants. Turkey's wind energy market may be summarized as follows [44,48,49]:

(a) Aegean, Marmara, and East-Mediterranean regions of Turkey are generally seen as promising higher wind power potential compared to other parts of Turkey.
(b) Turkey's total theoretically available potential for wind power is estimated to be around 88,000 MW.
(c) Turkey's total economically feasible potential for wind power is estimated at some 10,000 MW.

Table 5
An evaluation of Turkey's hydropower plants (HPPs) as of the end of 2002 [44]

Status	Total number of HPPs	Installed capacity		Energy			
				Average		Reliable	
		MW	% of total	GW h	% of the total	GW h	% of total
In operation	130	12,241	34	44,460	35	32,841	42
Under construction	31	3346	9	10,773	9	6610	8
Final project available	19	3570	10	10,897	9	7029	9
Final project under preparation	21	1334	4	4494	4	2492	3
Planning report available	119	6092	17	22,324	18	10,861	14
Planning report under preparation	57	1978	6	7602	6	4214	5
Master planning report available	40	2691	8	9195	7	5674	7
Preliminary investigation report available	107	3920	11	15,184	12	8523	11
First study available	42	368	1	1180	1	526	1
Total	566	35,539	100	126,109	100	78,770	100

(d) The electrical energy produced by wind power plants amounts to 48 GW h as of the end of 2002.
(e) Present applications have shown that wind energy in Turkey is a promising alternative and the strong development of wind energy is expected to continue in the coming years following restructuring of the Turkish electricity market.

8. Turkey's electric power capacity development

There is a critical importance of electricity in the energy sector. We observe that demand for electricity is increasing even in industrialized countries using this energy [44]. In the following subject, electric power development in Turkey will be briefly reported.

8.1. Electric power installed capacity

Turkey's total electricity capacity increased from 16,318 MW in 1990 to 31,846 MW in 2002, as can be seen in Table 6 [16,44]. It is clear from this table, that in 2002, about 61% of the total installed capacity was obtained from thermal resources and the rest from hydro (38.4%), wind and geothermal resources. Until 1985, in the thermal production, lignite-fired power plants had the largest share in the total thermal capacity. Since then, the contribution of the lignite-fired power plants has gradually decreased, while there has been a rapid increase in the natural gas-burned power plants [44]. In 2002, the share of the natural gas-fired plants in the total installed capacity was 30.4%, followed by the coal- and oil-fired power plants at 20.4 and 8.5%, respectively.

Turkey's rapid growth in electricity demand, which has led to almost a doubling of installed generating capacity over the past decade, is expected to continue for the foreseeable future [21]. Fig. 1 shows a breakdown of the electricity installed capacity by resources and puant demand between 2003 and 2012 [16], while that of electricity installed capacity by utilities and resources is also given in detail in Table 7. As can be seen from this table, Turkey's total electric power installed capacity will reach 40,989 MW in 2009 and this figure will continue up to 2012 according to the outcome of the electricity planning studies. Of this capacity, about 65% will be met by the power plants of EUAS, of which hydro accounts for some 53%. Total installed and obtainable power of plants in operation, under construction and with licenses, is also indicated in Table 8a–c [16]. An investigation of these tables concludes that thermal power plants will account for 65 and 42% of the total installed capacities of plants to be operated and constructed in 2012, respectively.

In July 2000, Turkey canceled its plans for building a 1400 MW_c nuclear power plant at Akkuyu Bay on its Mediterranean coast. Prior to the cancellation, three international consortia badi for the US$ 2.5 billion contract [21]. However, the data on electricity

Table 6
Distribution of electricity installed capacity and production by resources between 1990 and 2002 [16,44]

Resource	1990		1995		2000		2002	
	MW	% of total	MW	% of total	MW	% of total	MW	% of total
Hard coal	332	2.0	326	1.5	480	1.8	480	1.5
Lignite	4874	29.9	6048	28.8	6510	23.8	6503	20.4
Natural gas	2210	13.5	2884	13.8	4905	18.0	9702	30.4
Petroleum	1748	10.7	1353	6.5	1586	5.8	2700	8.5
Hydro	6764	41.5	9863	47.1	11,175	41.0	12,241	38.4
Wind	N/A	N/A	N/A	N/A	19	0.1	19	0.1
Geothermal	18	0.1	18	0.1	18	0.1	18	0.1
Others[a]	372	2.3	462	2.2	2571	9.4	183	0.6
Total	16,318	100.0	20,954	100.0	27,264	100.0	31,846	100.0

[a] Others include plants burning wood wastes, liquid sulfur, black liquor, bitumen pyrite, sulfur cake and multifuel.

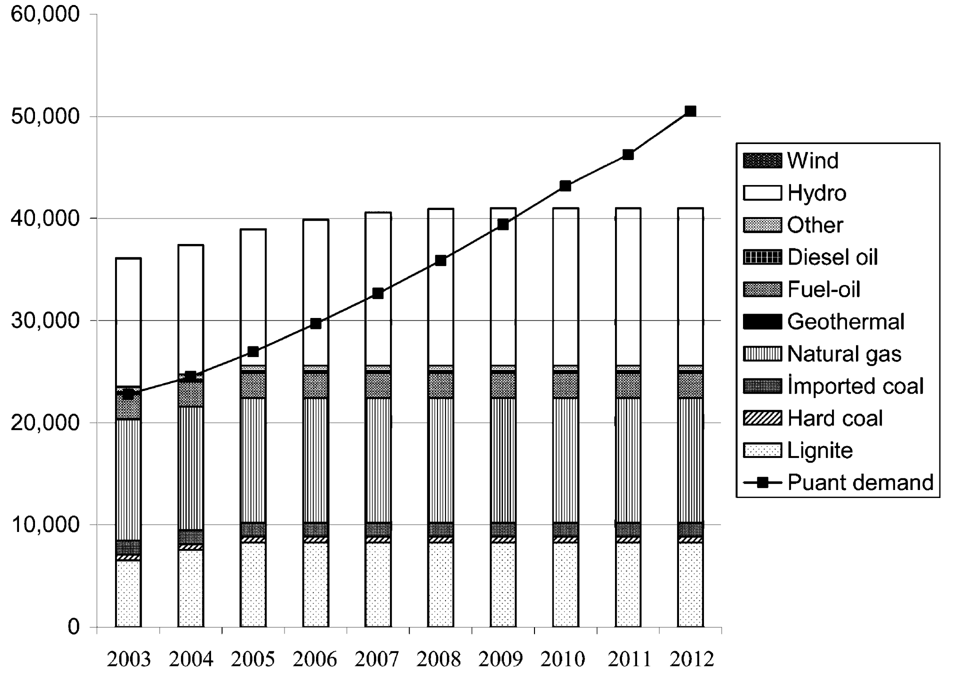


Fig. 1. Breakdown of the electricity installed capacity by resources and puant demand between 2003 and 2012 in MW [16].

projections may change depending on the revision to be made on the electricity planning taking into account nuclear power.

8.2. Electric energy production capacity

Although net electricity generation in Turkey has more than doubled over the past decade, it is not sufficient to keep up with expected demand. As a result, Turkey imports electricity, and has signed an agreement with its neighbor, Bulgaria, which will allow Turkey to purchase 33.7 billion kW h of electricity over the 10-year period from 1999 to 2009. This deal has had implications for future power plant construction planning, because import of electricity from Bulgaria, at ¢3–3.5 per kW h, is actually cheaper than the incremental cost of producing electricity from a new thermal-electric power plant (about ¢5 per kW h) [21].

Table 9 illustrates the distribution of electrical energy production by resources between 1990 and 2002 [16,44]. As can be seen from Table 9, in 2002, total electricity generation was realized at 129.4 TW h and natural gas had the biggest share in this distribution at about 40.6%, followed by hydro at 26%, coal at 24.8%, petroleum at 7.6% and the remainder at 1%. The distribution of electricity production by utilities in 2002 is shown in Table 10, where the contribution of the power plants of EUAS to Turkey's total consumption offered was the biggest at about 45% [16].

Table 7
Breakdown of Turkey's electricity installed capacity by utilities and resources in MW [16]

Utilities	Resources	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Power plants of EUAS	Fuel-oil	680	680	680	680	680	680	680	680	680	680
	Diesel oil	195	195	195	195	195	195	195	195	195	195
	Hard coal	300	300	300	300	300	300	300	300	300	300
	Lignite	5701	6741	7461	7461	7461	7461	7461	7461	7461	7461
	Natural gas	3903	3903	3903	3903	3903	3903	3903	3903	3903	3903
	Geothermal	15	15	15	15	15	15	15	15	15	15
	Other	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
	Hydro	11,530	11,580	12,298	13,186	13,867	14,208	14,268	14,268	14,268	14,268
	Subtotal	22,333	23,423	24,861	25,749	26,430	26,771	26,831	26,831	26,831	26,831
Power plants of transfer of operating rights	Lignite	620	620	620	620	620	620	620	620	620	620
	Hydro	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
	Subtotal	650	650	650	650	650	650	650	650	650	650
BO power plants	Natural gas	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600
	Imported coal	1210	1210	1210	1210	1210	1210	1210	1210	1210	1210
	Subtotal	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810
BOT power plants	Natural gas	1450	1450	1450	1450	1450	1450	1450	1450	1450	1450
	Hydro	884	884	884	884	884	884	884	884	884	884
	Wind	17	17	17	17	17	17	17	17	17	17
	Subtotal	2351	2351	2351	2351	2351	2351	2351	2351	2351	2351
Mobile power plants	Fuel-oil	863	863	863	863	863	863	863	863	863	863
	Diesel oil	15.3	15	15	15	15	15	15	15	15	15
	Subtotal	878	878	878	878	878	878	878	878	878	878

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Table 7 (*continued*)

Utilities	Resources	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Power plants of autopro-ducers	Fuel-oil	897	897	897	897	897	897	897	897	897	897
	Diesel oil	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
	Imported coal	145	145	145	145	145	145	145	145	145	145
	Hard coal	255.4	255.4	255.4	255.4	255.4	255.4	255.4	255.4	255.4	255.4
	Lignite	201.5	201.5	201.5	201.5	201.5	201.5	201.5	201.5	201.5	201.5
	LPG	67.9	67.9	67.9	67.9	67.9	67.9	67.9	67.9	67.9	67.9
	Natural gas	1962	2142	2142	2142	2142	2142	2142	2142	2142	2142
	Biogas	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
	Naphtha	377	377	377	377	377	377	377	377	377	377
	Other	25	25	25	25	25	25	25	25	25	25
	Hydro	129.4	129.4	142.9	180.7	180.7	180.7	180.7	180.7	180.7	180.7
	Wind	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	Subtotal	4084	4264	4278	4315	4315	4315	4315	4315	4315	4315
Power plants having production license	Natural gas	0	5	105	105	105	105	105	105	105	105
	Geother-mal	0	0	8	8	8	8	8	8	8	8
	Hydro	0	0	17	17	41	41	41	41	41	41
	Subtotal	0	5	130	130	154	154	154	154	154	154
Total		36,106	37,381	38,957	39,883	40,588	40,929	40,989	40,989	40,989	40,989

Table 8
Turkey's total installed and obtainable power of plants by energy resources in MW [16]

Years		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
(a) In operation											
Thermal total	Installed power	23,480	23,480	23,480	23,480	23,480	23,480	23,480	23,480	23,480	23,480
	Obtainable power	22,490	22,490	22,490	22,490	22,490	22,490	22,490	22,490	22,490	22,490
Hydro total	Installed power	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573
	Obtainable power	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573	12,573
Wind total	Installed power	19	19	19	19	19	19	19	19	19	19
	Obtainable power	19	19	19	19	19	19	19	19	19	19
Grand total	Installed power	36,072	36,072	36,072	36,072	36,072	36,072	36,072	36,072	36,072	36,072
	Obtainable power	35,082	35,082	35,082	35,082	35,082	35,082	35,082	35,082	35,082	35,082
(b) Under construction operation											
Thermal total	Installed power	33	1258	2086	2086	2086	2086	2086	2086	2086	2086
	Obtainable power	33	1258	2086	2086	2086	2086	2086	2086	2086	2086
Hydro total	Installed power	0	50	798	1724	2429	2770	2830	2830	2830	2830
	Obtainable power	0	50	798	1724	2429	2770	2830	2830	2830	2830
Wind total	Installed power	1	1	1	1	1	1	1	1	1	1
	Obtainable power	1	1	1	1	1	1	1	1	1	1

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Table 8 (*continued*)

Years		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Grand total	Installed power	35	1309	2885	3811	4516	4858	4918	4918	4918	4918
	Obtainable power	35	1309	2885	3811	4516	4858	4918	4918	4918	4918
(c) In operation, under construction and with licenses											
Thermal total	Installed power	23,513	24,738	25,566	25,566	25,566	25,566	25,566	25,566	25,566	25,566
	Obtainable power	22,523	23,748	24,576	24,576	24,576	24,576	24,576	24,576	24,576	24,576
Hydro total	Installed power	12,573	12,623	13,371	14,297	15,002	15,343	15,403	15,403	15,403	15,403
	Obtainable power	12,573	12,623	13,371	14,297	15,002	15,343	15,403	15,403	15,403	15,403
Wind total	Installed power	20	20	20	20	20	20	20	20	20	20
	Obtainable power	20	20	20	20	20	20	20	20	20	20
Grand total	Installed power	36,106	37,381	38,957	39,883	40,588	40,929	40,989	40,989	40,989	40,989
	Obtainable power	35,117	36,391	37,967	38,893	39,598	39,940	40,000	40,000	40,000	40,000
Puant power demand		22,800	24,519	26,939	29,710	32,663	35,887	39,382	43,173	46,237	50,520
Power standby	Installed power	13,306	12,862	12,018	10,174	7925	5043	1607	−2183	−5248	−9531
	Obtainable power	12,317	11,872	11,028	9184	6936	4053	617	−3173	−6238	−10,521
Power standby (%)	Installed power	58	52	45	34	24	14	4	−5	−11	−19
	Obtainable power	54	48	41	31	21	11	2	−7	−13	−21

Units are in MW except those denoted in the table.

Table 9
Distribution of electrical energy production by resources between 1990 and 2002 [16,44]

Resource	1990		1995		2000		2002	
	GW h	% of total	GW h	% of total	GW h	% of total	GW h	% of total
Hard coal	621	1.08	2232	2.59	3819	3.06	4093	3.16
Lignite	19,560	34.00	25,815	29.93	34,367	27.51	28,056	21.68
Natural gas	10,192	17.71	16,579	19.22	46,217	37.00	52,497	40.57
Petroleum	3942	6.85	5772	6.69	9311	7.45	9776	7.56
Hydro	23,148	40.22	35,541	41.21	30,879	24.72	33,684	26.03
Wind	N/A	N/A	N/A	N/A	33	0.02	48	0.04
Geothermal	80	0.14	86	0.10	76	0.06	105	0.08
Others	N/A		222	0.26	220	0.18	1141	0.88
Total	57,543	100.0	86,247	100.0	124,922	100.0	129,400	100.0

Sectoral electrical energy consumption development between 1990 and 2002 is indicated in Table 11. It is seen from this table that the electricity consumption of the industrial sector increased from 29.2 TW h in 1990 to 49.6 TW h in 2002, while its share decreased about 62.4–48.2% in the same years, respectively. On the other hand,

Table 10
Distribution of electricity production by utilities in 2002 [16]

Utilities	Production (million kW h)	Contribution to Turkey's total consumption offered (%)	Contribution to Turkey's subtotal production (%)
Power plants of Electricity Generation Incorporated Company (EUAS)	60,075.2	45.17	46.43
Power plants of affiliated partnerships of EUAS	17,256.9	12.98	13.34
Power plants of transfer of operating rights	4204.8	3.16	3.25
Mobile power plants	3208.8	2.41	2.48
CEAS power plants	4036.5	3.04	3.12
Kepez power plants	470.7	0.35	0.36
Power plants of production companies (BOT+BO)	19,700.0	14.81	15.22
Power plants of Autoproducers	20,446.6	15.37	15.80
Turkey's subtotal production	129,399.5	97.30	100.00
Bulgaria	3445.4	2.59	
Georgia	92.8	0.07	
Iran	50.1	0.04	
Total import	3588.3	2.70	
Turkey's total consumption offered	132,987.8	100.00	
Azerbaijan	435.1		
Export	435.1		
Turkey's total consumption	132,552.7		

Table 11
Sectoral electrical energy consumption development between 1990 and 2002 [44]

Resource	1990		1995		2000		2002	
	GW h	% of total	GW h	% of total	GW h	% of total	GW h	% of total
Industry	29,212	62.39	38,007	56.40	48,842	49.69	49,595	48.24
Residential	16,688	35.64	27,384	40.63	45,664	46.46	48,933	47.60
Agriculture	575	1.23	1513	2.24	3070	3.12	3442	3.35
Transport	345	0.74	490	0.73	720	0.73	830	0.81
Total	46,820	100.00	67,394	100.00	98,296	100.00	102,800	100.00
Per capita net consumption (kW h)	834		1092		1458		1476	

the consumption values for the industrial sector increased from 16.69 TW h (35.6%) in 1990 to 48.9 TW h (47.6%) in 2002. During the same period, there were not so important changes in the transportation sector, while per capita electricity net consumption reached from 835 to 1476 kW h in 1990 and 2002, respectively.

8.3. Evaluation results of Turkey's production projection between 2003 and 2012

Based on a study conducted by the Presidency of the Research, Planning and Coordination within the body of TEIAS in order to evaluate Turkey's production projection during a 10 year period from 2003 to 2012, the following may summarized [16]:

(a) Turkey's demand for electrical energy increased on average 7.3% annually in the last decade, while it is projected to continue to increase at an annual growth rate of 9.5%, using from 142.1 TW h in 2003 to 323.1 TW h in 2012. On the other hand, puant power demand is estimated to increase from 22,800 to 50,520 MW in the same period, respectively.
(b) According to the results of the production–consumption power balance, power standby figures are projected to be 58, 45, 24 and 4% in the years of 2003, 2005, 2007 and 2009, respectively, and to drop to minus figures in the following years due to inability to cover the demand. Production standby figures in the production-consumption balance prepared based on project productions are estimated at 25.7% in 2003, 18.8% in 2005, and 3.4% in 2007. Since then, they will take minus values due to not meeting the demand. Reliable production standby figures in the production-consumption balance prepared based on reliable productions are foreseen to be 16, 8.5 and 0 in 2003, 2005 and 2006, respectively, dropping to minus values since then.
(c) Based on the development of the domestic and imported resources in the installed capacity in the coming decade, the ratios of these resources are projected to be 54.5 and 45.5% in 2003, while they are 59.2 and 40.8% in 2009, respectively.
(d) In case where all thermal facilities will generate as much power as their production capacities, the consumption of natural gas at 15.4 Bcm in 2003 is projected to reach 17 Bcm in 2012 at a growth rate of 10%, while that of lignite at 46.2 Mt in 2003 is

estimated to increase to 83.4 Mt in 2012 at a growth rate of 81%. In the case of the electricity production at their reliable capacities, these above mentioned figures for natural gas and lignite are foreseen to grow from 15.3 Bcm and 42.3 Mt in 2003 to 16.8 Bcm and 70.9 Mt in 2012, at rates of 10 and 68%, respectively.

9. The Turkish air quality regulation and energy related emissions

9.1. The Turkish air quality regulation

The main principles of the Turkish environmental policy have been identified as management of natural resources enabling continuous economic development through protection of human health and natural balance and leaving natural, physical and social environment to the future generations which they deserve. On the other hand, the fundamental objective of the energy sector is to supply reliable, inexpensive and high-quality energy to all consumer sectors wherever and when ever required at appropriate price and to sustain economic and social development in an environmentally sound way. In this regard, for the co-ordination of environment and energy policies in Turkey, the formation of a dynamic and applicable energy-environment policy has been adopted. The Air Quality Protection Regulation (AQPR) was issued in November 1986, while its revision studies are still in progress. The purpose of the AQPR is to bring under control emissions in the form of soot, smoke, dust, gases, steam and aerosols diffused into the atmosphere as a result of any activities; to protect human beings and their environment from hazards arising from pollution of the air as a receptor medium; to eliminate the adverse effects of air pollution which cause serious damage to the public and neighborly relations and to ensure that such effects are not created [50].

The Environmental Impact Assessment Regulation was put into force on 7 February 1993. The purpose of this regulation is to regulate the administrative and technical principles which will be obeyed during the process of environmental impact assessment to be realized with a view to identify and to evaluate all possible impacts on environment of investment decisions of all public or private organizations, institutions and agencies whose proposed activities may cause environmental problems; to prevent or mitigate the adverse impacts which may cause any harm to the environment and to asses the alternatives of the activities [50].

9.2. Energy related emissions

Turkey is seeking admission to the European Union and is trying to meet European Union (EU) environmental standards. In this regard, it is required that Turkey have flue gas desulfurization (FGD) units on all newly commissioned coal power plants, Turkey is also retrofitting FGD on to older units [21].

In the framework of the Turkish energy policy, indigenous lignites have the importance in the energy supply of the country, particularly in power generation. However, due to the low calorific value and high sulfur content of low rank lignite, the SO_x emissions created

from the lignite-fired power plants are above the limit values specified in the AQPR, requiring the construction of FGD plants. Therefore, according to the AQPR, the construction of FGD plants for existing lignite-fired power plants has been conducted within a priority rank. As a consequence of the construction of FGD plants operating with an efficiency of 95%, a considerable amount of reduction in the SO_2 emissions per unit of electricity generated can be achieved gradually by the years. By comparison, the emission values were 13.29 and 11.6 tons SO_2/GW h in 1990 and 1998, respectively, with the projected value of 2.87 tons SO_2/GW h in 2010 [9].

Turkey's carbon emissions have risen in line with the country's energy consumption. Since 1980, Turkey's energy-related carbon emissions have jumped from 18 Mt annually to 55 Mt in 2000. Compared to other IEA countries, Turkey's energy and carbon intensities are low, but per capita energy consumption and per capita carbon emissions trend upwards [51,52].

Turkey's energy-related CO emissions reached from 129 Mt in 1990 to 204 Mt in 2000, with an annual growth rate of 4.7%. As of 2000, Turkey ranks 22nd and 74th among the world countries in terms of total CO_2 emissions in Mt and CO_2 emissions per capita, respectively, while Turkey's CO_2 emission share in the Organization for Economic Cooperation and Development (OECD) countries is 1.6%. On the basis of emissions per unit of gross domestic product (GDP), Turkey ranks 55th. In the framework of the planning studies conducted by the MENR, the value of CO_2 emissions corresponding to an energy consumption of 154 million toe by 2010 is expected to be 404 Mt, with the CO_2 emissions per capita of 5.3 ton [44].

Turkey is not a party to the UN Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol, meaning the country has no binding requirements to cut carbon emissions by the 2008–2012 period as most other IEA countries have. However, Turkey has established a National Climate Coordination Group (NCCG) to carry out the national studies in line with those conducted by all countries of the UNFCC. The Climate Coordination Group has published several influential findings, including the 'National Report on the Protection of the Atmosphere and Climate Change' and a 'National Report on Energy and Technology'. Armed with the research of the NCCG and with studies underway for a National Climate Program, Turkey is considering accession to the Kyoto Protocol. Additional pressure to meet EU standards makes it increasingly likely that Turkey will accept some level of binding emission reduction requirements in the foreseeable future [52].

10. Energy utilization efficiency in the Turkish utility sector

In a study performed by Utlu and Hepbasli [53], Turkey's energy utilization efficiency in the utility sector in 2000 was analyzed. As indicated in Table 12, there was totally 1140.30 PJ of energy and 1126.98 PJ of exergy inputs to the utility sector for electricity production. Energy (first law) and exergy (second law) efficiency values were found to be $\varepsilon_1 = 39.45\%$ and $\varepsilon_2 = 39.90\%$, respectively. It should be noticed that there is no significant difference between energy and exergy efficiencies. Including the transmission and distribution losses within the utility sector, overall energy ($\varepsilon_{1,o}$) and exergy ($\varepsilon_{2,o}$) efficiencies

Table 12
Performance of Turkey's conversion sector in 2000 [53]

Energy carrier	Energy input (exergy input) (PJ)		Resource (%)	Sector (%)	Turkey (%)	Electricity produced		ε_1 and ε_2 (%)
						PJ	%	
Power plants								
Hard coal	Energy	50.49	12.98	4.54	1.50	13.75	3.06	27.23
	Exergy	52.00		4.73	1.43			26.44
Lignite	Energy	460.65	86.23	41.42	13.81	123.72	27.51	26.86
	Exergy	479.01		43.58	13.05			25.82
Petroleum	Energy	125.04	8.46	11.24	3.57	33.52	7.45	26.81
	Exergy	123.79		11.26	3.55			27.08
Natural gas	Energy	361.17	63.22	32.47	9.57	166.38	37.00	46.07
	Exergy	332.28		30.23	10.24			50.07
Bio-mass	Energy	0	0	0	0	0.79	0.18	0
	Exergy	0		0	0			0
Hydropower	Energy	138.76	100	9.98	4.00	111.16	24.72	80.11
	Exergy	138.76		10.10	3.93			80.11
Renewable	Energy	3.92	6.05	0.35	0.03	0.39	0.08	10.01
	Exergy	1.14		0.10	0.11			34.53
All electricity	Energy	1140.03		100	32.47	449.72	100	39.45
	Exergy	1126.98		100	32.32			39.90
In-plant usage. Transmission and other losses						106.38	23.65	30.11
Export						1.57	0.35	30.47
Electricity supply to oil refineries						7.76	1.73	
Net electricity supply to end-users						334.03	74.27	
Oil refineries								
						Oil produced		
Crude oil		1411.77	95.58	100	40.34	1341.18	100	95.03
		1397.65		100	40.60	1327.77		
Export						68.07	5.08	
						67.39		
Oil supply to power plants						125.04	9.32	
						123.79		
Net oil supply to end-users						1148.07	85.60	
						1136.59		
Coke production facilities								
					Coke production			
Hard coal		106.86	27.48	100	3.05	85.58	100	80.08
		110.07		100	3.19	89.86	100	81.64

Net coke supply to end-users including import. Note that ε_1 and ε_2 are calculated from output/input but are assumed to be 80% for hydropower.

for the utility sector in Turkey were obtained to be 30.11 and 30.47%, respectively. About 5% of petroleum processed in the refineries was exported, while 9.32% of that was used in power plants for generating electricity. Coke facilities production accounted for 27.48% of the hard coal with a conversion efficiency of about 80% [53].

11. Conclusions

Energy is the basic building block of economic development. Electricity is the most flexible form of energy that constitutes one of the vital infra-structural inputs in socio-economic development [54]. The main conclusions that may be drawn from the present study are listed below.

(a) Parallel to the Energy Market Licensing Regulation and the Electricity Market Tariffs Regulation in August 2002 being put into effect, restructuring of the Turkish electricity market has gained a big importance.
(b) Turkey's demand for electrical energy increased on average 7.3% annually in the last decade, while it is expected to continue to increase at an annual growth rate of 9.5%, reaching 323.1 TW h in 2012.
(c) In Turkey, electricity is produced by thermal power plants (TPPs), geothermal energy, wind energy, and hydropower plants. Thermal resources meet approximately 60% of Turkey's total installed capacity for electric power generation, while 75% of total electricity is generated from TPPs.
(d) The share of coal in Turkey's total PE consumption is expected to increase from 32% in 1999 to 40% in 2020. The coal share of energy consumed in Turkey for electricity generation is also projected to remain fairly constant, increasing from 26% in 1999 to 27% in 2020 [35].
(c) The energy and exergy efficiency values are found to be 30.11 and 30.47% in 2000 for the Turkish utility sector. This has clearly shown the necessity of the planned studies toward increasing energy and exergy efficiencies in this sector [53].
(f) Similar to other industrializing countries, with the increases in energy consumption and economical growth, energy related environmental problems are rapidly growing in Turkey. To control these problems for sustainable development, energy related policy should be well determined and to minimize the adverse environmental impacts of energy activities, just as energy related environmental decisions should take account of the energy consequences [50].
(g) Turkey is not a party to the UNFCCC or the Kytoto Protocol, meaning the country has no binding requirements to cut carbon emissions by the 2008–2012 period as most other IEA countries have. However, it has been rehabilitating the power plants since 1987 [50,52].
(h) The electricity losses come from the transmission and distribution systems. The loss in the transmission line of Turkey is about 2.5–3%, which is within world standards. However, the distribution loss is considerably high at 15%. Concerning the TOOR of electricity distribution facilities to private sector, it is expected that the distribution losses will be reduced [4,44].

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